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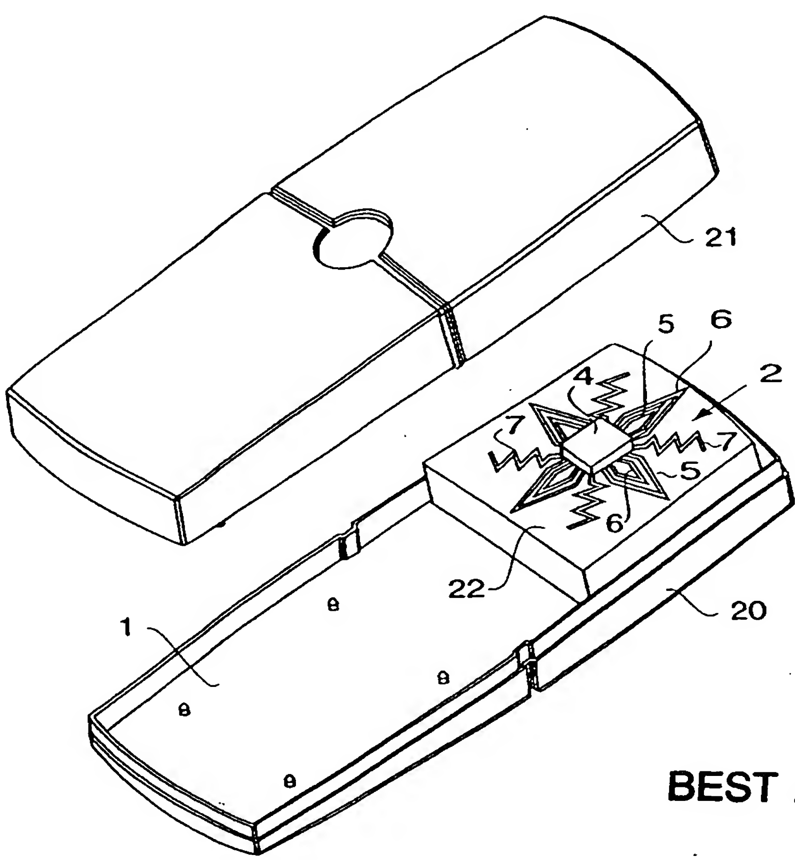
(54) Title: AN ANTENNA DEVICE FOR TRANSMITTING AND/OR RECEIVING RF WAVES



(57) Abstract: An antenna device for transmitting and/or receiving RF waves connectable to a radio communication device and comprising a radiating structure (2) with at least two switchable antenna elements (5, 6, 7). The device comprises switching means for selectively connecting and disconnecting the antenna elements, arranged in a central switching unit (4). Further, at least two antenna elements (5, 6, 7) are connected to the switching unit (4), so that they can be individually switched between different coupling states. The switching unit (4) has a control port for reception of control signals enabling the switching unit to effect a centralized switching of the antenna elements. The invention also relates to a radio communication device comprising one or more antenna devices of that kind, and to a method for transmitting and receiving RF waves.

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AN ANTENNA DEVICE FOR TRANSMITTING AND/OR RECEIVING RF WAVES

FIELD OF THE INVENTION

The present invention relates to an antenna device for transmitting and/or receiving RF waves connectable to a radio communication device, to a radio communication device comprising one or more antenna devices of that kind, and to a method for transmitting and receiving RF waves.

BACKGROUND OF THE INVENTION

In the radio communication systems of today there is an ever increasing demand for making the user devices smaller. This is especially important when it comes to hand portable terminals, e.g. mobile phones. The design of the hand portable terminals must permit the terminals to be easily and rapidly manufactured at low costs. Still the terminals must be reliable in use and exhibit a good performance.

It is well known that the size of an antenna is critical for its performance, see Johnson, Antenna Engineering Handbook, McGrawHill 1993, chapter 6. The interaction between antenna, phone body and the close-by environment, such as e.g. the user himself, will become more important than ever. Since recently, there is also normally a requirement that two or more frequency bands shall be supported.

This puts requirements on the antenna device to be compact, versatile and to have good antenna performance. However, the performance varies depending on the design of the terminal in which it is to be used and depending on objects in the close-by environment of

the device.

When manufacturing a hand portable phone today the antenna is tailored to the characteristics of this specific phone and to be suited for a "normal" use in a "normal" environment. This means that the antenna cannot later on be adapted to any specific condition under which a certain phone is to be used or to suit a different phone. Thus, each model of a hand portable phone must be provided with a specifically designed antenna, which normally cannot be optimally used in any other phone model.

The radiating properties of an antenna device for a small-sized structure, e.g. for a hand portable terminal, such as a portable phone, heavily depend on the shape and size of the support structure, e.g. a printed circuit board, PCB, of the phone, and also on the phone casing. All radiation properties, such as resonance frequency, input impedance, radiation pattern, impedance, polarization, gain, bandwidth, and near-field pattern are products of the antenna device itself and its interaction with the PCB and the phone casing. On top of this, objects in the close-by environment affect the radiation properties. Thus, all references to radiation properties made below are intended to be for the entire device in which the antenna is incorporated.

What has been stated above is true also with respect to radio communication systems used in other apparatuses than portable phones, such as cordless telephones, telemetry systems, wireless data terminals, etc. Thus, even if the antenna device of the invention is described in connection with portable phones it is applicable on a broad scale in various radio communication apparatuses.

PRIOR ART

US-A1-5,541,614 discloses an antenna system including a set of center-fed and segmented dipole antennas embedded on top of a frequency selective photonic bandgap crystal. Certain characteristics of the antenna system can be varied by connecting/disconnecting segments of the dipole arms to make them longer or shorter, for instance.

This prior art antenna system requires four feed lines, which complicates the manufacture of the device and increases the risk of undesired interaction with the antenna function. Further, the MEMS switches used are distributed in the pattern of antenna segments, which also makes the manufacture more complicated as, for instance, all switches must be provided with a separate control line in order to be individually controllable.

WO 99/44307 discloses a wireless communication apparatus with antenna-gain diversity. The apparatus comprises a first and a second antenna element, of which both or only one can be coupled to an antenna-signal node. The antenna element not coupled to the node is electrically coupled to signal ground.

EP-A1-0,546,803 discloses a diversity antenna comprising a single antenna element. The antenna element is in the form of a quarter wave monopole, which can be fed alternately at one end, or the other from a common RF feed source.

EP-A2-0,840,394 discloses a phased array radar system. This system employs programmable MEMS switches and transmission lines to provide true time delays or phase shifts in order to steer the array beam.

However, none of these prior art arrangements describes

any versatile antenna device, which can be adapted to a wide variety of conditions, especially to conditions in the close-by environment of the device, by controlling a central switching unit.

SUMMARY OF THE INVENTION

In this disclosure it is to be understood that the antenna device of the invention is operable to transmit and/or receive RF signals. Even if a term is used herein that suggests one specific signal direction it is to be appreciated that such a situation can cover that signal direction and/or its reverse.

A main object of the present invention is to provide a versatile antenna device for a radio communication device, which antenna device is adaptable to various conditions and for obtaining desired functions.

It is also an object of the invention to provide an antenna device, which can be adapted in order to suit different communication apparatuses, such as different models of hand portable phones, after it has been mounted in the apparatus.

Another object of the invention is to provide an antenna device, of which certain characteristics are easily controllable, such as radiation pattern, tuning, polarization, resonance frequency, bandwidth, input impedance, gain, diversity function, near-field pattern, connection of antenna elements as receiving/transmitting elements.

An additional object of the invention is to provide an antenna device comprising switchable antenna elements and which antenna device is easy to manufacture, and exhibits a controllable interaction between the switching means and the antenna elements.

A further object of the invention is to provide an antenna device suited to be used as an integrated part of a radio communication device.

A particular object of the invention is to provide an antenna device, preferably for receiving radio waves, comprising a patch antenna device switchable between at least two different frequency bands.

These and other objects are attained by an antenna device as claimed in claims 1, 29 and 61, by a radio communication device as claimed in claim 33, and by a method as claimed in claims 34, 45, and 62, respectively.

In the claims the expression "antenna elements" is intended to include antenna elements that are connected to an RF feed device, are RF-grounded or are disconnected.

The invention is described in greater detail below with reference to the embodiments illustrated in the appended drawings. However, it should be understood that the detailed description of specific examples, while indicating preferred embodiments of the invention, are given by way of example only, since various changes and modifications within the scope of the claims will become apparent to those skilled in the art reading this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of two casing parts of a portable telephone including one embodiment of an antenna device according to the present invention.

Figs. 2-14 schematically display additional embodiments of an antenna device according to the invention.

Fig. 15 is a flow diagram of an example of a switch-and-stay algorithm for controlling a central switching unit of an inventive antenna device.

Fig. 16 is a flow diagram of an alternative example of an algorithm for controlling a central switching unit of an inventive antenna device.

Fig. 17 is a flow diagram of a further alternative example of an algorithm for controlling a central switching unit of an inventive antenna device.

Fig. 18 is a schematic top view of a further embodiment of an antenna device of the present invention.

Fig. 19 is a schematic elevation view of the embodiment of Fig. 18.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In Fig. 1 reference numerals 20, 21 are the front part and the back part, respectively, of the casing of a portable telephone. The main printed circuit board, PCB, of the phone is intended to be mounted in the space 1 in the front part of the casing. An antenna device 2 of the present invention is printed on a separate supporting device 22 in this embodiment. The support can be a flexible substrate, an MID (Molded Interconnection Device) or a PCB. However, the antenna could have been printed on the main PCB, as well, which can extend along the length of the front part of the casing. Between the phone circuit on the PCB and the antenna device there are RF feed lines and control lines (not shown) for the switching unit.

The antenna device 2 comprises a central switching unit 4. The unit 4 comprises a matrix of electrically controllable switching elements. The switching elements

can include microelectro-mechanical system switches (MEMS), PIN diode switches, or GaAs field effect transistors, FET.

The switching unit 4 is surrounded by a pattern of antenna elements. Each antenna element is connected to a respective switch in the switching unit arranged for connecting and disconnecting the antenna element. In this embodiment the radiating structure comprises four loop-shaped antenna elements 5. Within each of the loops 5 a loop-shaped parasitic element 6 is formed. Between each pair of loop-shaped elements 5, 6 a meander-shaped antenna element 7 is arranged. The antenna elements form a symmetrical pattern around the switching unit 4. However, in certain applications the antenna elements can form an unsymmetrical pattern in order to build in different antenna characteristics in different directions. Further, the radiation structure can include additional antenna elements not connected to the switching unit.

By means of the switching unit 4 the loop-shaped antenna elements can be connected in parallel or in series with each other, or some elements can be connected in series and some in parallel. Further, one or more elements can be completely disconnected or connected to an RF ground. One or more of the meander-shaped antenna elements 7 can be used separately or in any combination with the loop antenna elements. The meander elements can also be segmented so that only one or more selected portions thereof can be connected if desired.

Although not illustrated in Fig. 1, other types of antenna elements, such as patch antennas, slot antennas, whip antennas, spiral antennas, and helical antennas can also be used as will be described below.

In all cases, the switching unit may or may not be surrounded by the antenna elements. The switching unit can also be positioned on one side.

All switching of the antenna elements is centralized to the switching unit 4, which can be very small with a controllable interaction with the antenna function. Further, as all switching is centralized to the unit 4, switch control signals need only be supplied to that unit which simplifies the overall antenna structure among other things. These are important advantages of the present invention over prior art solutions.

By means of the central switching unit 4 the connection/disconnection of the antenna elements is easily controllable. By appropriate selection of the combination of antenna elements which is connected to the RF feed means, i.e. the antenna configuration state, the impedance and/or the resonance frequency of the antenna device can be adjusted without the need for separate connection or disconnection of discrete components. The same effect can be achieved by using parasitic elements, not connected to RF feed, but connected to RF ground or unconnected. The parasitic elements can also be connected to the switching unit. In case it would be desired also to use discrete components in any application these can be easily connected or disconnected by means of the same central switching unit as the other antenna elements.

Further, the radiation pattern of the antenna can be shaped according to demand by appropriate selection of antenna elements. In this way losses due to objects in the close-by environment of the antenna device, such as the user of a portable phone, can be minimized among other things. It will also be possible to control the tuning, polarization, bandwidth, resonance frequency,

radiation pattern, gain, input impedance, near-field pattern of the antenna device, to include a diversity function, and to change an antenna element from being an element connected to the transmitter circuitry to be an element connected to the receiver circuits of a radio communication device.

The above-mentioned parameters of a small-sized radio communication device are affected by objects in the proximity of the device. By proximity or close-by environment is here meant the distance within which the effect on the antenna parameters is noticeable. This distance extends roughly about one wavelength from the device. By altering the antenna configuration by means of the switching unit 4 this influence on the antenna parameters by an external object can be reduced to a varying but important extent.

Below, the invention will be described in further detail with reference to Figs. 2-12, which schematically illustrate some basic patterns of antenna elements according to the invention.

Fig. 2 is an example of an antenna device comprising a plurality of loop antenna elements 5, 6 as in Fig. 1. The loop antenna elements are arranged so that they start and end at the switching unit 4. By means of the switching unit the loop elements can be connected to an RF feed line, short-circuited, coupled in series or in parallel with each other. Each element can therefore be seen as a portion of the total antenna structure, from now on called "the total antenna", which properties are determined by the state of the switching unit 4. That is, the switching unit decides how the loop element portions are connected and electrically arranged. At least some of the elements 5 can act as an actively radiating element, where the excitation is achieved

through direct connection to an RF feed. Possibly, some of the elements 6 can act as parasitic elements, where the excitation of the elements is achieved through parasitic coupling to other antenna elements.

The loop antenna elements can be shaped as three-dimensional structures. Parts or all of the structure can be positioned above the PCB. The pattern can go around, or through the PCB, so that part of the pattern is on the other side of the PCB. Some or all parts of the pattern can extend perpendicularly to the PCB.

There can be permanent shorting pins and/or components attached to the antenna elements outside of the switching device. The feeding of the antenna elements can also take place outside of the switching device.

The purpose of changing the switch state can be to tune the total antenna to a desired frequency. This can be done by connecting several loop elements in series so that the electrical length is appropriate for the desired frequency.

Another purpose can be to match the antenna to a desired impedance. This can be done by switching in/out parasitic elements. The mutual coupling between the elements adds to the input impedance of the active element, changing the resulting input impedance in a desired manner.

Yet another purpose can be to change the radiation pattern of the total antenna. This can be done by altering the connection of antenna portions so that the radiating currents are altered. This can also be done by switching in/out parasitic elements, thereby directing or reflecting the radiation towards a desired direction.

Fig. 3 shows an example of the antenna device, where two meandering antenna elements 7 are connected to the central switching unit 4. The expression "meandering" element is intended also to cover other elements with similar shape and function, such as zigzag shape, snake shape, fractal shape, etc. What has been stated above in connection with the loop antenna elements in Fig. 2 is applicable also regarding the meander-shaped elements of Fig. 3, as is realized by the person skilled in this art, the only difference being the inherent difference in radiation characteristics between these two types of antenna elements, as is well known in the art.

In Fig. 3 the reference numerals 8 indicate connection lines, by means of which the RF feed and/or RF ground points of the meander element can be switched between different positions along the element. The aim of this can be to change the input impedance for matching purposes or to change the current flow for radiation pattern control.

Fig. 4 shows an example of an antenna device, where slot antenna elements 9 are connected to the central switching unit 4. The slot antenna elements are connected to the switching unit via connection lines 10. The lines 10 can be connected directly to an RF feed device, shorted, coupled in series or in parallel with lines to other antenna elements. Each connection line can act as an active feed line and be connected directly to an RF feed device. One can also use a parasitic coupling, where there is no direct connection to any RF feed.

At least one slot element 9 of the antenna device is fed by at least one connection line 10, and in various ways tuned by the other lines. For example, the other

lines can be shorted or left open so that the slot antenna element, and in effect the whole antenna device, is tuned for a desired frequency band. The same technique can be used to change the radiation pattern of the wireless terminal, to which the antenna device is coupled, pattern-shaping. Moreover, connecting, disconnecting or tuning other slot elements can provide tuning or pattern-shaping.

Fig. 5 shows an example of an antenna device similar to that of Fig. 4 but where two patch antenna elements 11 are connected to the central switching unit 4 via connection lines 12. The patch antenna elements are placed closed to or in connection to the central switching unit. What has been stated above in connection with Fig. 4 is relevant also for the embodiment of Fig. 5.

The purpose of changing the switch state can be to tune the total antenna to a desired frequency. This can be done by connecting several patch antenna elements in series so that the electrical length of the resulting antenna is appropriate for the desired frequency.

Another purpose can be to match the antenna to a desired impedance. This can be done by switching in/out RF ground at some connection points not connected to RF feed, or by changing the connection point that is connected to RF feed. This can also be done by switching in/out parasitic elements. The mutual coupling between the elements contributes to the input impedance of the active element, changing the resulting input impedance in a desired manner.

Yet another purpose can be to change the radiation pattern of the total antenna. This can be done by altering the connection of antenna portions so that the

radiating currents are altered. This can also be done by switching in/out parasitic elements, thereby directing or reflecting the radiation towards a desired direction.

Fig. 6 shows an example of an antenna device, where a meander element 7 is connected to the central switching unit 4 together with a whip antenna element 13.

The whips and meander elements can be connected directly to an RF feed device, shorted or coupled in parallel/series. Each element can act as an active radiating element, that is be connected directly to an RF feed device or as a parasitic element, where there is no galvanic connection to an RF feed device.

For example, the electrical length of the whip 13 and/or the meander 7 can be altered to tune the resonance frequency. There can be other parasitic elements, not shown, close to the whips and/or the meander for tuning and/or for changing the radiation pattern. In this way the radiation pattern can be mainly directed towards a desired direction. The whip element can be replaced by a helical antenna element or combined with such.

Of course, the antenna device can comprise a central switching unit and any combination of the above described antenna elements forming a symmetrical or an unsymmetrical pattern of radiating elements. Some examples are shown in Figs. 7-12, in which the reference numerals stand for the same elements as in the previous Figs. 1-6. Each antenna element can be used separately or in any combination with the other elements. The elements themselves can also be combinations of various antenna types, such as meandered loop patterns and combined patch and meander

patterns, etc.

Further, some antenna elements can be used as receiving antennas and some elements as transmitting antennas. The antenna device can be adapted for operation in several frequency bands and for receiving and transmitting radiation of different polarization. In addition the switching unit 4 can be used to connect or disconnect discrete matching components. The invention is not limited to any specific shape of the individual antenna elements as the shapes can be chosen according to the desired function.

A small-sized wireless device, such as a mobile phone, can be used in many different ways. It can for example be held to the ear as a telephone, it can be put in a pocket, it can be attached to a belt at the waist, it can be held in the hand, or it can be put on a metal surface. Many more scenarios can be found, and they can all be referred to as different usage scenarios. Common for all scenarios is that there may be objects in the proximity of the device, thereby affecting the antenna parameters of the device. Usage scenarios with differing objects in the proximity of the device have different influence on the antenna parameters.

Below are listed two specific usage scenarios:

Free Space scenario (FS): The device is held in free space, i.e. with no objects in the proximity of the device. Air surrounding the device is considered free space. Many usage scenarios can be approximated with this scenario. Generally, if the scenario has little influence on the antenna parameters, it can be referred to as free space.

Talk Position scenario (TP): The device is held to the ear by a person, as a telephone. The influence on the

antenna parameters varies depending on which person is holding the device and exactly how the device is held. Here, the TP scenario is considered a general case, covering all individual variations mentioned above.

Various radiation-related parameters that may be controlled by means of an antenna device in accordance with the invention will be described in more detail with reference to Figs. 13 and 14.

RESONANCE FREQUENCY (FIG. 13)

Antennas for wireless radio communication devices experience detuning due to the presence of the user. For many antenna types, the resonance frequency drops considerably when the user is present (TP), compared to when the device is positioned in free space (FS). An adaptive tuning between free space, FS, and talk position, TP, can reduce this problem substantially.

A straightforward way to tune an antenna is to alter its electrical length, and thereby altering the resonance frequency. The longer the electrical length is, the lower is the resonance frequency. This is also the most straightforward way to create band switching, if the change in electrical length is large enough.

In Fig. 13 is shown a meander-like antenna structure 35 arranged together with a central switching unit 36 comprising a plurality of switches 37-49. Antenna structure 35 may be seen as a plurality of aligned and individually connectable antenna elements 50-54, which are connectable to a feed point 55 through the switching unit 36 and a feed line 56. Feed point 55 is further connected to a low noise amplifier of a receiver circuitry (not shown) of a radio communication device, and hence antenna structure 35 operates as a receiving antenna. Alternatively, feed point 55 is

connected to a power amplifier of a radio communication transmitter for receiving an RF power signal, and hence antenna structure 35 operates as a transmitting antenna.

A typical example of operation is as follows. Assume that switches 37 and 46-49 are closed and remaining switches are opened and that such an antenna configuration state is adapted for optimal performance when the antenna device is arranged in a hand-portable telephone located in free space. When the telephone is moved to talk position, the resonance frequency will be lowered by influence of the user and thus, in order to compensate for the presence of the user, switch 49 is opened, whereby the electrical length of the connected antenna structure is reduced and accordingly the resonance frequency is increased. This increase shall with an appropriate design of antenna structure 35 and switching means 36 compensate for the reduction as introduced when the telephone is moved from free space to talk position.

The same antenna structure 35 and switching means 36 may also be used for switching between two different frequency bands such as GSM900 and GSM1800.

For instance, if an antenna configuration state, which includes antenna elements 50-53 connected to feed point 55 (switches 37 and 46-48 closed and remaining switches opened), is adapted to suit the GSM900 frequency band, switching to the GSM1800 frequency band may be effectuated by simply opening switch 47, whereby the electrical length of the presently connected antenna structure (elements 50 and 51) is reduced to approximately half the previous length, implying that the resonance frequency is approximately doubled, which would be suitable for the GSM1800 frequency band.

According to the invention all switching of the elements 50-54 required for different purposes is centralized to the switching unit 36, which is provided with a single feed line.

IMPEDANCE (FIG. 14)

Instead of tuning a detuned antenna, one can perform adaptive impedance matching, which involves letting the resonance frequency be slightly shifted and compensate this detuning by means of matching.

An antenna structure can have feed points at different locations. Each location has a different ratio between the E and H fields, resulting in different input impedances. This phenomenon can be exploited by switching the feed point, provided that the feed point switching has little influence on the resonance frequency of the antenna. When the antenna experiences detuning due to the presence of the user (or other object), the antenna can be matched to the feed line impedance by altering for example the feed point of the antenna structure. In a similar manner, RF ground points can be altered.

In Fig. 14 is schematically shown an example of such an implementation of an antenna structure 61 that can be selectively grounded at a number of different points spaced apart from each other. Antenna structure 61 is in the illustrated case a planar inverted F antenna (PIFA) mounted on a printed circuit board 62 of a radio communication device. Antenna 61 has a feed line 63 and N different spaced RF ground connections 64. By switching from one RF ground connection to another, the impedance is slightly altered.

As before all switching functions are centralized to a central switching unit 60.

Moreover, switching in/out parasitic antenna elements can produce an impedance matching, since the mutual coupling from the parasitic antenna element to the active antenna element produces a mutual impedance, which contributes to the input impedance of the active antenna element.

Other typical usage positions than FS and TP can be defined, such as for instance waist position, pocket position, and on an electrically conductive surface.

Each case may have a typical tuning/matching, so that only a limited number of points needs to be switched through. If outer limits for the detuning of the antenna elements can be found, the range of adaptive tuning/matching that needs to be covered by the antenna device can be estimated.

One implementation is to define a number of antenna configuration states that cover the tuning/impedance matching range. There can be equal or unequal impedance difference between each antenna configuration state.

RADIATION PATTERN

The radiation pattern of a wireless terminal is affected by the presence of a user or other object in its near-field area. Loss-introducing material will not only alter the radiation pattern, but also introduce loss in radiated power due to absorption.

This problem can be reduced if the radiation pattern of the terminal is adaptively controlled. The radiation pattern (near-field) can be directed mainly away from the loss-introducing object, which will reduce the overall losses.

A change in radiation pattern requires the currents

producing the electromagnetic radiation to be altered. Generally, for a small device (e.g. a hand-portable telephone), there need to be quite large changes in the antenna structure to produce altered currents, especially for the lower frequency bands. However, this can be done by switching to another antenna type producing different radiation pattern, or to another antenna structure at another position/side of the PCB of the radio communication device.

Another way may be to switch from an antenna structure that interacts heavily with the PCB of the radio communication device (e.g. whip or patch antenna) to another antenna not doing so (e.g. loop antenna). This will change the radiating currents dramatically since interaction with the PCB introduces large currents on the PCB (the PCB is used as main radiating structure).

ALGORITHMS (FIG. 15-17)

An object in the near-field area of a device will alter the antenna input impedance. Therefore, a measure of the reflection coefficient on the transmitter side, e.g. the Voltage Standing Wave Ratio, VSWR, may be a good indicator of when there are small losses. Small changes in VSWR as compared to VSWR of free space imply small losses due to nearby objects. However, other optimization parameters than WSWR can be used, such as measures of received signal quality, e.g. Bit Error Rate, BER, Carrier to Noise Ratio, C/N, Carrier to Interference Ratio, C/I, received signal strength, or a combination of two or more measurable quantities. Also the received signal strength and measures of the diversity performance, e.g. the correlation between the signals, can be used. If the transmitter and receiver antennas are separated an algorithm can take information from the transmitter antenna (e.g. VSWR) to

tune the receiver antenna, and the other way around. The optimization parameters are treated in some kind of algorithm in order to determine the states of the switches in the central switching unit.

The discussion above concerns the antenna near field and losses from objects in the near field. However, by means of an antenna in accordance with the present invention it will be possible to direct a main beam in the far-field area in a favorable direction producing good signal conditions. Similarly, the polarization can be changed in a desired manner.

The invention will be exemplified below by means of some algorithms, which use the reflection coefficient as an optimization parameter. In the following examples we use VSWR as a measure of the reflection coefficient. However, the algorithms can be implemented with any other measure of operation parameters.

All described algorithms will be of trial-and-error type, since there is no knowledge about the new state until it has been reached.

Below, with reference to Figs. 15-17, some exemplary algorithms for controlling the antenna are depicted.

The simplest algorithm is probably a switch-and-stay algorithm as shown in the flow diagram of Fig. 15. Here switching is performed between predefined states i = 1, ..., N (e.g. N = 2, one state being optimized for FS and the other state being optimized for TP). A state i = 1 is initially chosen, whereafter, in a step 65, the VSWR is measured. The measured VSWR is then, in a step 66, compared with a predefined limit (the threshold value). If this threshold is not exceeded the algorithm is returned to step 65 and if it <u>is</u> exceeded there is a switching performed to a new state i = i + 1. If i + 1

exceeds N, switching is performed to state 1. After this step the algorithm is returned to step 65.

Using such an algorithm, each state 1,..., N is used until the detected VSWR exceeds the predefined limit. When this occurs the algorithm steps through the predefined states until a state is reached, which has a VSWR below threshold. Both the transmitter and receiver antenna structures can be switched at the same time. An arbitrary number of states may be defined, enabling switching to be performed between a manifold of states.

Another example is a more advanced switch-and-stay algorithm as shown in the flow diagram of Fig. 16. In the same way as the previous algorithm, N states are predefined, and a state i = 1 is initially chosen, whereafter, in a step 68, the VSWR is measured, and, in a step 69, compared with the threshold value. If the threshold is not exceeded the algorithm is returned to step 68, but if it is exceeded, a step 70 follows, wherein all states are switched through and VSWR is measured for each state. All VSWR's are compared and the state with the lowest VSWR is chosen.

Step 70 may look like:

```
for i = 1 to N
    switch to State i
    measure VSWR(i)
    store VSWR(i)
switch to State of lowest VSWR
```

Finally, the algorithm is returned to step 68. Note that this algorithm may require quite fast switching and measuring of the VSWR, since all states have to be switched through.

A further alternative algorithm particularly suited for

an antenna structure has a manifold of predefined antenna configuration states, which may be arranged so that two adjacent states have radiating properties that deviates only slightly. In Fig. 17 is shown a flow diagram of such a further algorithm.

N states are predefined, and initially a state i = 1 is chosen and a parameter VSWRold is set to zero, and a variable "change" is set to +1. In a first step 71 VSWRi (VSWR of state i) is measured and stored, whereafter in a step 72 the VSWRi is compared with VSWRold. If, on one hand, VSWRi < VSWRold a step 73 follows, wherein "change" is set to + "change" (this step is not really necessary). Steps 74 and 75 follow, wherein VSWRold is set to present VSWR, i.e. VSWRi, and the antenna configuration state is changed to i + "change", i.e. i = i + "change", respectively. The algorithm is then returned to step 71. If, on the other hand, VSWRi > VSWRold, a step 76 follows, wherein variable "change" is set to - "change". Next, the algorithm continues to step 74 and 75. Note that in this case the algorithm changes "direction".

It is important to use a time delay to run the loops (71, 72, 73, 74, 75, 71 and 71, 72, 76, 74, 75, 71, respectively) only at specific time steps, as the switched state is changed at every loop turn. At 72 a present state (VSWRi) is compared with the previous one (VSWRold). If the VSWR is better than the previous state, a further change of state in the same "direction" is performed. When an optimum is reached the antenna configuration state as used will typically oscillate between two adjacent states at every time step. When end states 1 and N, respectively, are reached, the algorithm does not continue further to switch to states N and 1, respectively, but stays preferably at the end states until it switches to

states 2 and N-1, respectively.

The algorithm assumes relatively small differences between two adjacent states, and that the antenna configuration states are arranged so that the changes are decreasing in one direction and increasing in the opposite direction. This means that between each state there is a similar quantity of change in, for example, resonance frequency. For example, small changes in the separation between RF feed and RF ground connections at a PIFA antenna structure would suit this algorithm perfectly, see Fig. 14.

In all algorithms there may be a time delay to prevent switching on a too fast time scale. It may also be necessary to perform the switching in specific time intervals adapted to the operation of the radio communication device.

As a further alternative (not shown in the Figures), a control means of the antenna device may hold a look-up table with absolute or relative voltage standing wave ratio (VSWR) ranges, of which each is associated with a respective state of the central switching unit. Such a provision would enable control means to refer to the look-up table for finding an appropriate state given a measured VSWR value, and for adjusting the switching unit to the appropriate antenna configuration state.

The means and methods for controlling the states of the central switching unit to optimize the antenna performance are further detailed in our two co-pending Swedish patent applications Nos. 9903944-8 and 9903943-0, entitled "Antenna device and method for transmitting and receiving radio waves", and filed on October 29, 1999, which applications hereby are incorporated by reference.

EMBODIMENT OF FIGS. 18 AND 19

Turning now to Figs. 18 and 19, which are a schematic top view and an elevation view, respectively, of an antenna device, a further embodiment of the present invention will be depicted.

The antenna device comprises a single, essentially planar patch antenna element 81 provided with three different slots 83, 85 and 87 and adjacent thereto a switching box 89, which typically comprises an array or a matrix of electrically controllable switching elements (not illustrated). Such switching elements can be PIN diode switches, or GaAs field effect transistors, FET, but are preferably microelectro-mechanical system switches (MEMS).

The patch antenna element 81 is provided with a number of RF feed and ground connection points 91, 93, 95 and 97, respectively, to each of which a respective RF feed or ground connector 101, 103, 105, and 107 is connected. Each of these connectors 101, 103, 105, and 107 is further connected to a respective switch in the switching box 89, which switch in turn is connected to an RF feed line or to ground (not illustrated).

The switching box is controlled by means of control signals supplied via one or several control lines (not illustrated) such that switching box may connect and disconnect the various RF feed and ground connectors 101, 103, 105, and 107.

The antenna element 81 is arranged on a dielectric support 109, which in turn is mounted on the main printed circuit board, PCB, 111 of a radio communication device, e.g. a mobile phone (not illustrated). The switching box 89 is arranged on a support 113, which in turn is mounted on PCB 111.

Support 113 is arranged to house or carry ground connectors and RF feed and control lines interconnected between the switching box and the PCB. Preferably, the PCB is itself operating as a ground plane or similar for the antenna device.

In this particular embodiment, the antenna device is a receiver (RX) antenna device arranged for triple-band switching. Thus, the slots 83, 85 and 87, and the switchable RF feed and ground connectors 101, 103, 105, and 107 may be arranged in three different switched states optimized for receiving radio signals in three different frequency bands.

In the first of these switched states connector 101, being a ground connector, is connected to ground, connector 103, being an RF feed connector, is connected to an RF feed line, and the other connectors 105 and 107 are disconnected. Thus, opposite sides of slot 83, are connected to an RF feed line and to ground, respectively, and a slot antenna is obtained, which by way of inter alia dimensions and shape of slot 83, and positions of RF feed point 93 and ground point 91, respectively, may be optimized for receiving radio signals in e.g. the CDMA800/DAMPS800 band with a center frequency of 881.5 MHz, see Table 1. Obviously, dimensions, shapes, and locations of inter alia the patch element 81, the other slots 85 and 87 as well as of the dielectric support 109 and the PCB 111 affect the resonance frequency and the input impedance of this first switched antenna state.

Table 1. Frequency ranges, bandwidths (BW), and center frequencies (f_0) of various radio communication frequency bands. All units in MHz.

Band	frequency	BW	T_x	R_x
CDMA 800 /DAMPS 800	824 – 894	70	824-849 (BW=25, f_0= 836.5)	869-894 (BW=25, f_0= 881.5)
GSM 900	890 – 960	70	890 – 915 (BW=25, f_0= 902.5)	935 – 960 (BW=25, f_0= 947.5)
DCS 1800 /PCN	1710-1880	170	1710-1785 (BW=75, f_0= 1747.5)	1805-1880 (BW=75, f_0= 1842.5)
CDMA 1900 /PCS 1900	1850-1990	140	1850-1910 (BW=60, f_0= 1880)	1930-1990 (BW=60, f_0= 1960)
CDMA 2000 /UMTS	1920-2170	250	1920-1980 (BW=60, f_0= 1950)	2110-2170 (BW=60, f_0= 2140)

In the second of these switched states connector 105, being a ground connector, is connected to ground, connector 107, being an RF feed connector, is connected to an RF feed line, and the other connectors 101 and 103 are disconnected. Thus, opposite sides of slot 85, are connected to an RF feed line and to ground, respectively, and a slot antenna is obtained, which by way of inter alia dimensions and shape of slot 85, and positions of RF feed point 97 and ground point 95, respectively, may be optimized for receiving radio signals in e.g. the GSM900 band with a center frequency of 947.5 MHz, see Table 1.

In the third of these switched states connector 107, being an RF feed connector, is connected to an RF feed line, and the other connectors 101, 103 and 105 are disconnected. Thus, no connected ground connector is needed. Here, slot 87 may, by way of inter alia dimensions and shape, and positions of RF feed point 97, be optimized for receiving radio signals in e.g. the CDMA2000/UMTS band with a center frequency of 2140 MHz, see Table 1.

All antenna switched states are preferably optimized such that a relatively high input impedance of e.g. 50-400Ω, or 100-300Ω, or about 200Ω, is obtained. By separating the RX and TX branches of the antenna function, each branch may be better and/or more easily optimized. A TX antenna device would then be optimized such that a relatively low impedance of e.g. 5-30Ω is obtained.

The RF feed connectors are preferably wires, cables or the like, whereas the ground connectors are preferably strips, pins, blocks or the like.

It shall be appreciated that this embodiment of the

invention may be modified in order to achieve dual-band switching (in which case only two slots are needed) as well as to achieve an antenna device operating in more than three frequency bands.

It shall further be appreciated that this embodiment of the invention may be modified in order to achieve an antenna device for transmitting radio frequency waves or to achieve an antenna device for both receiving and transmitting radio frequency waves.

It shall yet further be appreciated that this embodiment of the invention may encompass more RF feed and/or ground connection points, to each of which an RF feed line or a ground connector may be connected and disconnected by means of the switching box in order to alter the performance, e.g. the resonance frequency, the impedance and the radiation pattern, of the antenna device. Reference is here made to the embodiments depicted above in this description.

It shall still further be appreciated that this embodiment of the invention may encompass more than one antenna element, wherein each of these antenna elements may be selectively connected and disconnected by means of the switching box.

It shall yet further be appreciated that this embodiment of the invention may encompass passive as well as active electrical components connectable between opposite sides of any of the slots of the antenna device.

It will be obvious that the invention may be varied in a plurality of ways. Such variations are not to be regarded as a departure from the scope of the invention. All such modifications as would be obvious to one skilled in the art are intended to be included within

the scope of the appended claims.

It shall particularly be appreciated that the various embodiments as depicted in the present application may be combined in any suitable manner in order to obtain yet further embodiments of the present invention.

CLAIMS

1. An antenna device for transmitting and/or receiving RF waves connectable to a radio communication device, comprising:

- a radiating structure (2, 35) comprising at least two switchable antenna elements (5, 6, 7, 9, 11, 13, 50-54); and

- switching means (37-49) for selectively connecting and disconnecting said antenna elements;

characterized by

- said switching means being arranged in a central switching unit (4, 36);

- said at least two antenna elements (5, 6, 7, 9, 11, 13, 50-54) being connected to said switching unit (4, 36), so that they can be individually switched between different coupling states; and

- said switching unit (4, 36) having a control port for reception of control signals enabling the switching unit to effect a centralized switching of the antenna elements.

2. An antenna device according to claim 1, wherein

- an RF feed device is connected to the central switching unit (4, 36), so that the antenna elements (5, 6, 7, 9, 11, 13, 50-54) can be fed with RF signals via said switching unit.

3. An antenna device according to claim 1 or 2, wherein

- an RF ground device is connected to the central switching unit (4, 36), so that the antenna element (5,

6, 7, 9, 11, 13, 50-54) can be RF grounded via said switching unit.

4. An antenna device according to any of claims 1-3,

wherein

- at least one antenna element (61) is provided with a plurality of spaced connection points (63, 64) adapted to be connectable to an RF feed means or to RF ground; and

- said connection points (63, 64) are connected to the central switching unit, so that said unit can switch the RF feed point and/or the RF ground point between different positions on the antenna element (61).

5. An antenna device according to any of claims 1-4,

wherein

- said switching unit (4, 36) is arranged to be able to switch each antenna element (5, 6, 7, 9, 11, 13) of the radiating structure (2) in any of the manners of the group consisting of connecting an element to an RF feed device in series or in parallel with any other antenna element, connecting an antenna element as a parasitic element, short-circuiting an antenna element, and completely disconnecting an antenna element.

6. An antenna device according to any of claims 1-5,

wherein

- said radiating structure (2) comprises at least one permanently and parasitically coupled antenna element.

7. An antenna device according to any of claims 1-6,

wherein

- the central switching unit (4, 36, 60) is arranged to be controlled in dependence on one or more measurable optimization parameters of the antenna performance.

8. An antenna device according to claim 7, wherein

- the optimization parameter or parameters are selected from the group consisting of measures of the transmitter reflection coefficient, e.g. the Voltage Standing Wave Ratio (VSWR), measures of received signal quality, e.g. the Carrier to Noise Ratio, (C/N), the Carrier to Interference Ratio, (C/I), and the Bit Error Rate (BER), the received signal strength, and measures of the diversity performance, e.g. the correlation between the signals.

9. An antenna device according to any of claims 1-8,

wherein

- the central switching unit (4, 36, 60) is arranged to be controlled to switch the radiating structure of antenna elements between a plurality of antenna configuration states, each of which is adapted for use of the antenna device in said radio communication device in a respective predefined operation environment.

10. An antenna device according to claim 9, wherein

- a first antenna configuration state of said plurality of antenna configuration states is adapted for use of the antenna device in said radio communication device in free space and a second antenna configuration state of said plurality of antenna configuration states is adapted for use of the antenna device in said radio communication device in talk position.

11. An antenna device according to claim 10 wherein

- a third antenna configuration state of said plurality of antenna configuration states is adapted for use of the antenna device in a radio communication device in waist position.

12. An antenna device according to claim 11, wherein

- a fourth antenna configuration state of said plurality of antenna configuration states is adapted for use of the antenna device in a radio communication device in pocket position.

13. An antenna device according to any of claims 1-12 wherein

- said switching unit (4, 36, 60) comprises a matrix of electrically controllable switching elements.

14. An antenna device according to claim 13, wherein

- said switching unit comprises a matrix including MEMS switches.

15. An antenna device according to claim 13, wherein

- said switching unit comprises a matrix including PIN diode switches.

16. An antenna device according to claim 13, wherein

- said switching unit comprises a matrix including GaAs FET switches.

17. An antenna device according to any of claims 1-16, wherein

- the switchable antenna elements are selected from the group consisting of loop elements, meander

elements, slot elements, patch elements, whip elements, spiral elements, and helical elements.

18. An antenna device according to any of claims 1-17,

wherein

- the antenna elements (5, 6, 7) of the radiating structure (2) form a symmetrical pattern around the central switching unit (4).

19. An antenna device according to any of claims 1-18,

wherein

- the antenna elements (5, 6, 7) of the radiating structure (2), and said central switching unit (4) are arranged in a common plane on a carrier board.

20. An antenna device according to claim 19, wherein

- said antenna elements (5, 6, 7) and said central switching unit (4) are arranged on a printed circuit board (1, 3) of the radio communication device connected to the antenna device.

21. An antenna device according to any of claims 1-18,

wherein

- the central switching unit is arranged in a plane spaced from the plane of the radiating structure.

22. An antenna device according to any of claims 1-18,

wherein

- the radiating structure or part thereof is shaped as a three-dimensional structure; and

- parts of the structure passes around an edge of

and/or through a printed circuit board of the radio communication device connected to the antenna device, so that there is a portion of the radiating structure on each of the two main surfaces of said printed circuit board.

23. An antenna device according to any of claims 1-18,

wherein

- the radiating structure or a portion thereof extends perpendicular to the main surfaces of a printed circuit board of the radio communication device.

24. An antenna device according to any of claims 1-23,

wherein

- the antenna elements and said central switching unit are arranged on a first surface of a carrier board;

- an RF feed device is arranged on an opposite surface of the carrier board; and

- an RF ground plane means is laminated in the carrier board.

25. An antenna device according to claim 24, wherein

- said RF feed device comprises a strip line.

26. An antenna device according to any of claims 1-25,

wherein

- at least two antenna elements, jointly operating as a transmitting antenna, are connectable to transmitting circuits of said radio communication device; and

- at least two antenna elements, jointly operating as a receiving antenna, are connectable to receiving cir-

cuits of said radio communication device.

27. An antenna device according to any of claims 1-26, wherein

- the antenna device comprises a first and a second radiating structure of switchable antenna elements, and a first and a second central switching unit each assigned to a respective one of the radiating structures;

- the first and the second radiating structures are separated from each other; and

- the antenna elements of the first radiating structure are connectable to transmitting circuits of the radio communication device, and the antenna elements of the second radiating structure are connectable to receiving circuits of the radio communication device.

28. An antenna device according to any of claims 1-27, wherein

- two antenna elements or two groups of antenna elements are controllable to supply receiving signals of low correlation to the radio communication device in order to obtain a diversity function.

29. An antenna device for transmitting and/or receiving RF waves connectable to a radio communication device, comprising:

- a radiating structure comprising at least one antenna element (61); and

- switching means connected to the at least one antenna element, wherein

- said at least one antenna element (64) is provided with a plurality of spaced connection points (63, 64) adapted to be connectable to an RF signal feed device or to ground;

- at least two of said connection points are connectable to the switching means;

- said switching means being arranged in a central switching unit (60); and

- said switching unit (60) having a control port for reception of control signals enabling the switching unit to effect a centralized switching of the connection points (63, 64).

30. An antenna device according to claim 29, wherein

- said connection points (63, 64) are arranged at short intervals, so that there is a limited change only of the antenna performance when switching the connection point of the RF feed or the RF ground between two adjacent connection points.

31. An antenna device according to claim 29 or 30, wherein

- the central switching unit (60) is arranged to switch the RF feed device and/or the RF ground sequentially between the connection points (63, 64) of the antenna element (61) to optimize one or more measurable optimization parameters of the antenna performance.

32. An antenna device according to any of claims 29-31, wherein

- the RF feed or the RF ground can be connected to more than one of said connection points (63, 64) at the same time.

33. A radio communication device comprising an antenna device according to any of claims 1-32.

34. A method for transmitting and/or receiving RF waves using an antenna device connectable to a radio communication device, and comprising a radiating structure comprising at least two switchable antenna elements, and switching means for selectively connecting and disconnecting said antenna elements, characterized by switching of the antenna elements centrally from a central switching unit including said switching means and to which said at least two antenna elements are individually connected.

35. A method according to claim 34, comprising

- feeding selected antenna elements with RF signals via said central switching unit.

36. A method according to claim 34 or 35, comprising

- RF grounding selected antenna elements via said central switching unit.

37. A method according to any of claims 34-36, comprising

- switching, by means of said central switching unit, the RF feed point and/or the RF ground point between different locations on an antenna element provided with a plurality of spaced connection points.

38. A method according to any of claims 34-37, comprising

- switching, by means of said switching unit, each antenna element of the radiating structure in any of the manners of the group consisting of connecting an element to an RF feed device in series or in parallel

with any other antenna element, connecting an antenna element as a parasitic element, short-circuiting an antenna element, and completely disconnecting an antenna element.

39. A method according to any of claims 34-38, comprising

- controlling the central switching unit in dependence on one or more measurable optimization parameters of the antenna performance.

40. A method according to claim 39, comprising

- controlling the central switching unit in dependence on a measurable optimization parameter selected from the group consisting of measures of the transmitter reflection coefficient, e.g. the Voltage Standing Wave Ratio (VSWR), measures of received signal quality, e.g. the Carrier to Noise Ratio, (C/N), the Carrier to Interference Ratio, (C/I), and the Bit Error Rate (BER), the received signal strength, and measures of the diversity performance, e.g. the correlation between the signals.

41. A method according to any of claims 34-40, comprising

- controlling the central switching unit for switching the radiating structure of antenna elements between a plurality of antenna configuration states;

- adapting a first of said plurality of states for use of the antenna device in said radio communication device in free space; and

- adapting a second of said plurality of states for use of the antenna device in said radio communication device in talk position.

42. A method according to claim 41, comprising

- adapting a third of said plurality of antenna configuration states for use of the antenna device in a radio communication device in waist position or in pocket position.

43. A method according to any of claims 34-42, comprising

- using a first radiating structure comprising at least two antenna elements connected to a first central switching unit as a transmitting antenna, and

- using a second radiating structure comprising at least two antenna elements connected to a second central switching unit as a receiving antenna.

44. A method according to any of claims 34-43, comprising

- controlling two antenna elements or two groups of antenna elements to supply receiving signals of low correlation to the radio communication device in order to obtain a diversity function.

45. A method for transmitting and/or receiving RF waves using an antenna device connectable to a radio communication device, and comprising a radiating structure comprising at least one antenna element, and switching means connected to the at least one antenna element, characterized by

- providing said at least one antenna element with a plurality of spaced connection points adapted to be connectable to an RF signal feed device or to RF ground,

- connecting at least two of said connection points to

the switching means arranged in a central switching unit, and

- effecting a centralized switching of the connection points from said switching unit.

46. A method according to claim 45, comprising

- switching the RF feed device and/or the RF ground sequentially between the connection points of the antenna element to optimize one or more measurable optimization parameters of the antenna performance.

47. The antenna device as claimed in claim 29, wherein

- said at least one antenna element is a patch antenna element (81) provided with at least a first (83) and a second (87) slot;

- said at least two of said connection points include a first (93) and a second (97) RF feed connection point; and

- said switching unit (89) is adapted to connect said RF feed connection points to said RF signal feed device one at a time.

48. The antenna device as claimed in claim 47, wherein it is optimized for receiving and/or transmitting RF waves in a first frequency band when said first RF feed connection point is connected and optimized for receiving and/or transmitting RF waves in a second frequency band when said second RF feed connection point is connected, said first and second frequency bands being different.

49. The antenna device as claimed in claim 48, wherein said first and second frequency bands are chosen from the group of CDMA800/DAMPS800, GSM900, DCS1800/PCN,

CDMA1900/PCS1900, and CDMA2000/UMTS.

50. The antenna device as claimed in any of claims 47-49, wherein

- said at least two of said connection points further include a first ground connection point (91); and

- said switching unit is adapted to connect said first ground connection point to ground concurrently with said first RF feed connection point being connected to said RF signal feed device.

51. The antenna device as claimed in claim 50, wherein

- said at least two of said connection points further include a second ground connection point (95); and

- said switching unit is adapted for connection of said second ground connection point to ground provided that said second RF feed connection point being connected to said RF signal feed device.

52. The antenna device as claimed in claim 51, wherein

- said patch antenna element (81) is provided with a third (85) slot; and

- said antenna device is optimized for receiving and/or transmitting RF waves in a third frequency band when said second RF feed connection point and said second ground connection point are connected, said third frequency band being different than said first and second frequency bands.

53. The antenna device as claimed in claim 52, wherein said first frequency band is the CDMA800/DAMPS800 band, said second frequency band is chosen from the group of DCS1800/PCN, CDMA1900/PCS1900, and CDMA2000/UMTS, and

said third frequency band is the GSM900 band.

54. The antenna device as claimed in any of claims 47-53, wherein it is adapted to receive RF waves and wherein it has a high input impedance, preferably 50-400Ω, more preferably 100-300Ω, and most preferably about 200Ω.

55. The method as claimed in claim 45, wherein

- said at least one antenna element is a patch antenna element (81) provided with at least a first (83) and a second (87) slot;

- said at least two of said connection points that are connected to the switching means include a first (91) and a second (97) RF feed connection point; and

- said RF feed connection points are connected to said RF signal feed device, one at a time, by means of said switching means.

56. The method as claimed in claim 55, wherein RF waves in a first frequency band are received and/or transmitted when said first RF feed connection point is connected and RF waves in a second frequency band are received and/or transmitted when said second RF feed connection point is connected, said first and second frequency bands being different.

57. The method as claimed in claim 56, wherein said first and second frequency bands are chosen from the group of CDMA800/DAMPS800, GSM900, DCS1800/PCN, CDMA1900/PCS1900, and CDMA2000/UMTS.

58. The method as claimed in any of claims 55-57, wherein

- said at least two of said connection points being

connected to the switching means further include a first ground connection point (91); and

- said first ground connection point is connected to ground concurrently with said first RF feed connection point being connected to said RF signal feed device.

59. The method as claimed in claim 58, wherein

- said at least two of said connection points further include a second ground connection point (95); and

- said second ground connection point is connected to ground provided that said second RF feed connection point being connected to said RF signal feed device.

60. The method as claimed in claim 59, wherein

- said patch antenna element (81) is provided with a third (85) slot; and

- said antenna device is optimized for receiving and/or transmitting RF waves in a third frequency band when said second RF feed connection point and said second ground connection point are connected, said third frequency band being different than said first and second frequency bands.

61. An antenna device for receiving and/or transmitting RF waves and being connectable to a radio communication device provided with RF circuitry, said antenna device being **characterized by**:

- a patch antenna element (81) provided with at least two slots (83, 87) and at least two spaced RF feed connection points (93, 97) such that the antenna device is adapted to receive and/or transmit RF waves in a first frequency band when a first (93) of said RF feed connection points is connected to said RF circuitry and

adapted to receive and/or transmit RF waves in a second frequency band when the other (97) of said RF feed connection points is connected to said RF circuitry, said first and second frequency bands being different; and

- a controllable switching device (89) adapted for connection and/or disconnection of said first and said other of the at least two RF feed connection points to and/or from said RF circuitry in dependence on being supplied with control signals.

62. In an antenna device for receiving and/or transmitting RF waves and being connectable to a radio communication device provided with RF circuitry, said antenna device comprising a patch antenna element (81) provided with at least two slots (83, 87) and at least two spaced RF feed connection points (91, 97) such that the antenna device is adapted to receive and/or transmit RF waves in a first frequency band when a first (91) of said RF feed connection points is connected to said RF circuitry and adapted to receive and/or transmit RF waves in a second frequency band when the other (97) of said RF feed connection points is connected to said RF circuitry, said first and second frequency bands being different, a method for switching between said at least two frequency bands **characterized by:**

- connecting said first of the at least two RF feed connection points to said RF circuitry and disconnecting said other of the at least two RF feed connection points from said RF circuitry and/or

- disconnecting said first of the at least two RF feed connection points from said RF circuitry and connecting said other of the at least two RF feed connection

points to said RF circuitry by means of a controllable switching device (89).

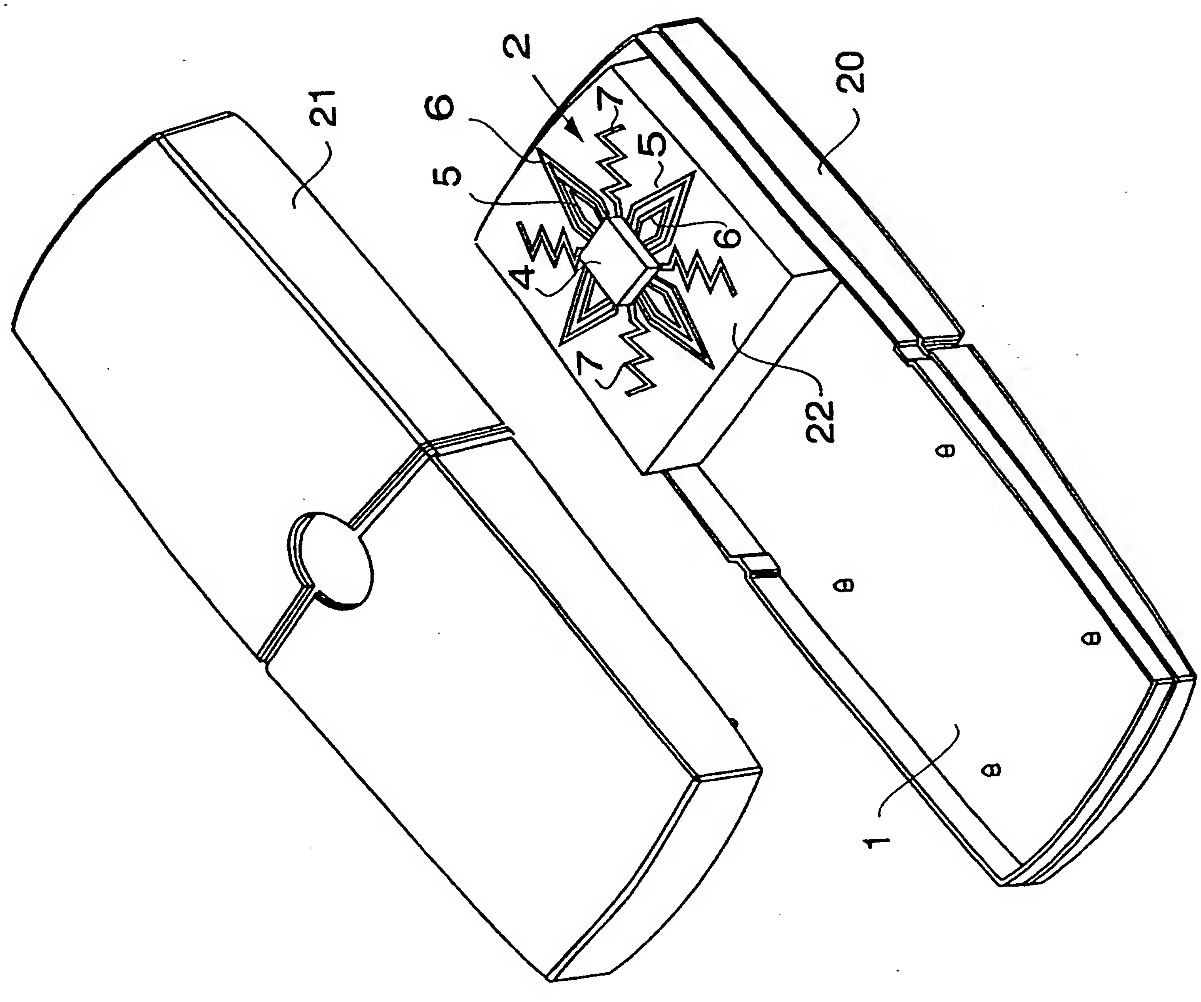

Fig. 1

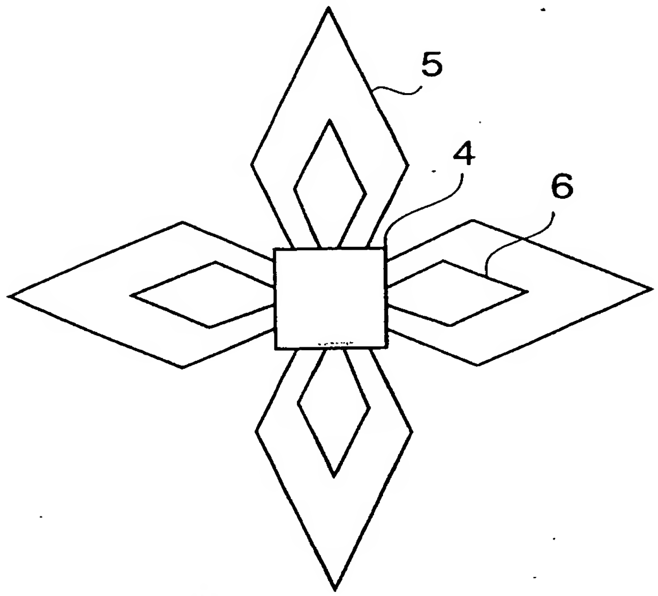

Fig. 2

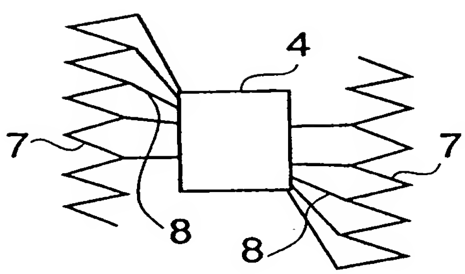

Fig. 3

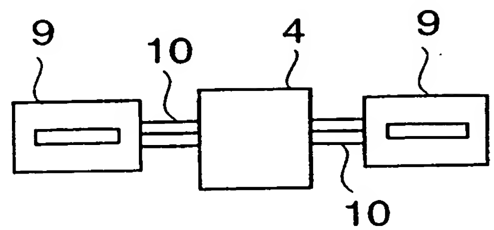

Fig. 4

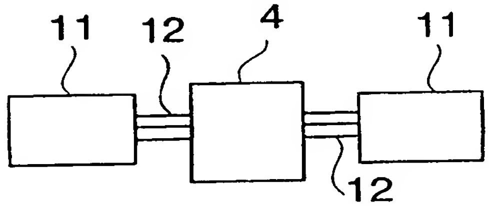

Fig. 5

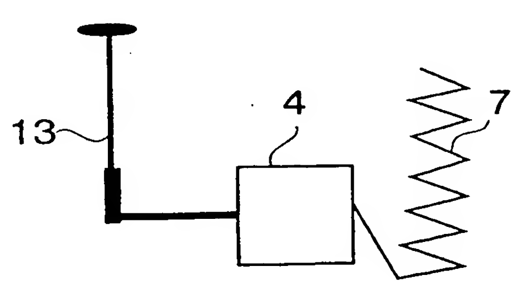

Fig. 6

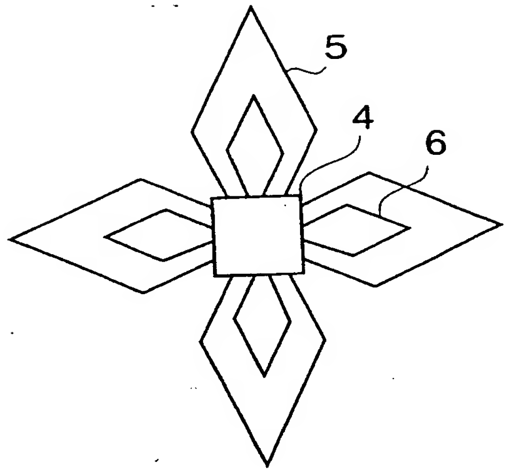

Fig. 7

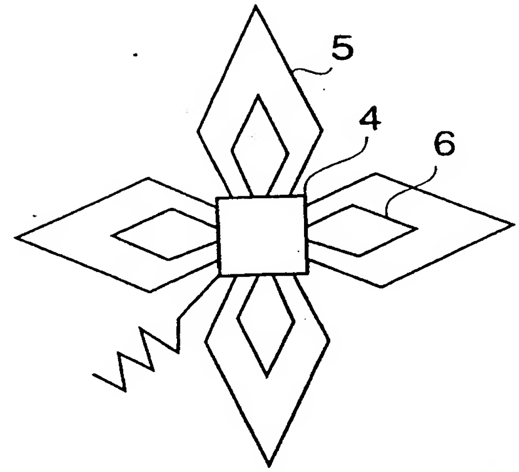

Fig. 8

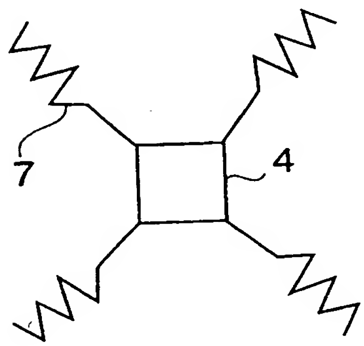

Fig. 9

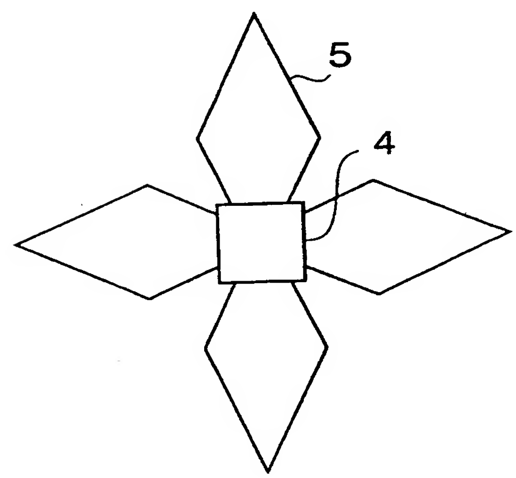

Fig. 10

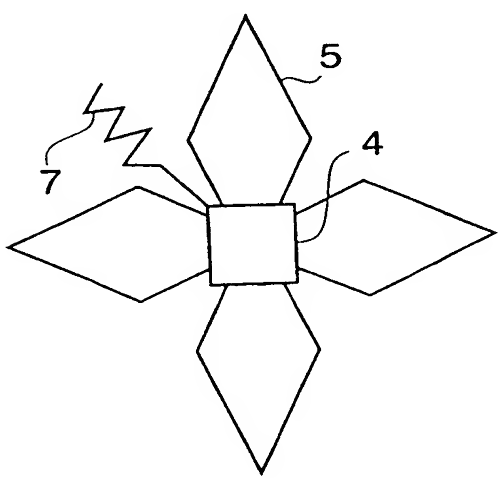

Fig. 11

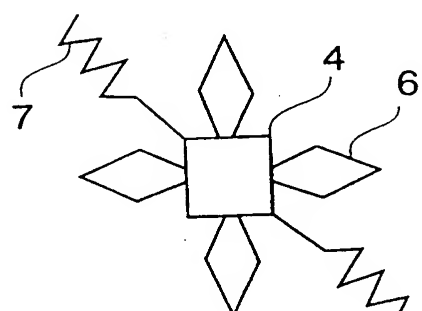

Fig. 12

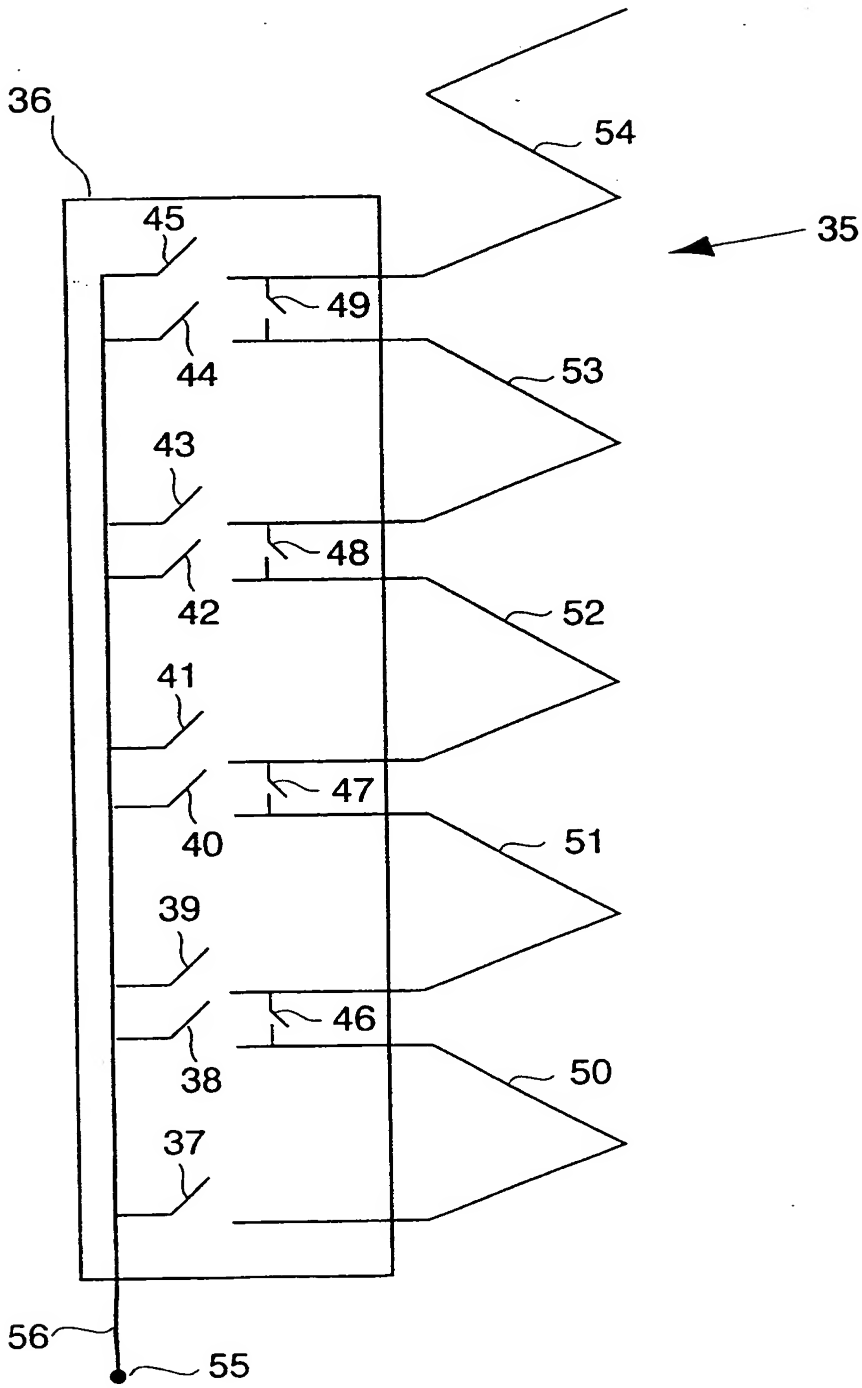

Fig. 13

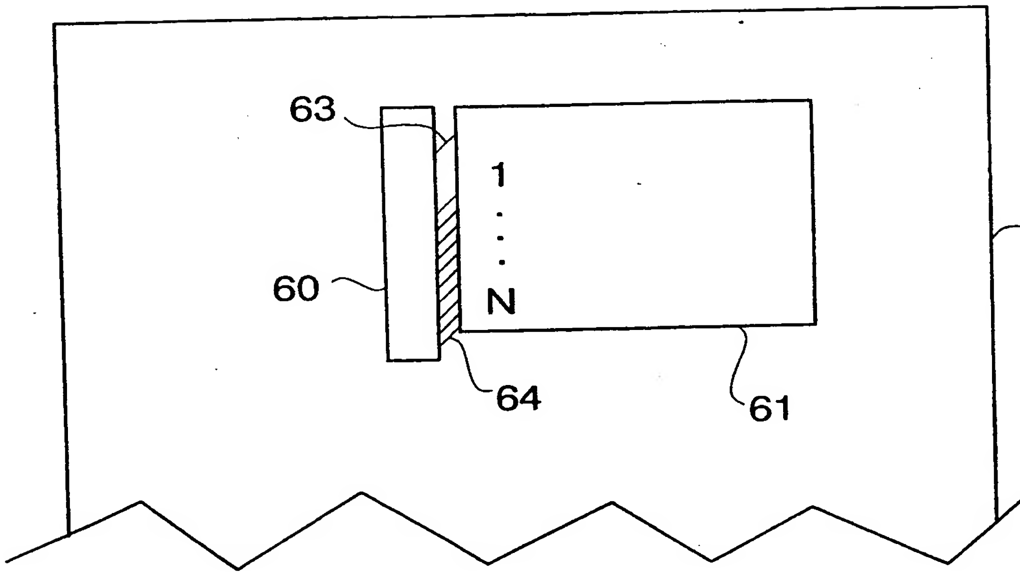
63
62
1
N
60
64
61

Fig. 14

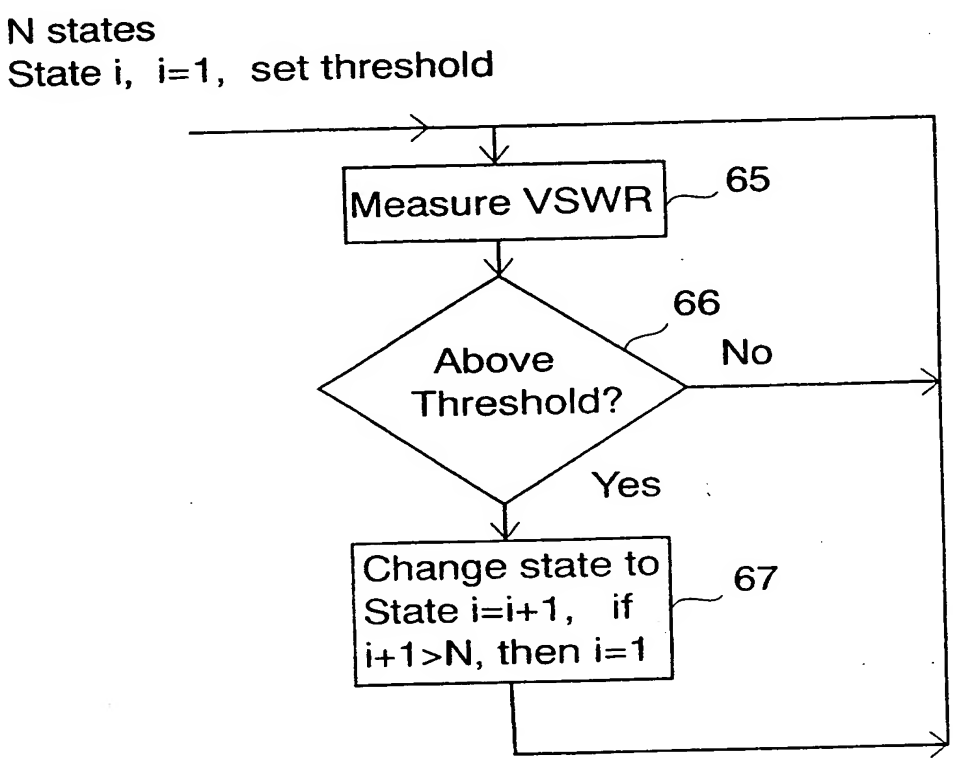
N states
State i, i=1, set threshold
Measure VSWR
65
66
Above Threshold?
No
Yes
Change state to State i=i+1, if i+1>N, then i=1
67

Fig. 15

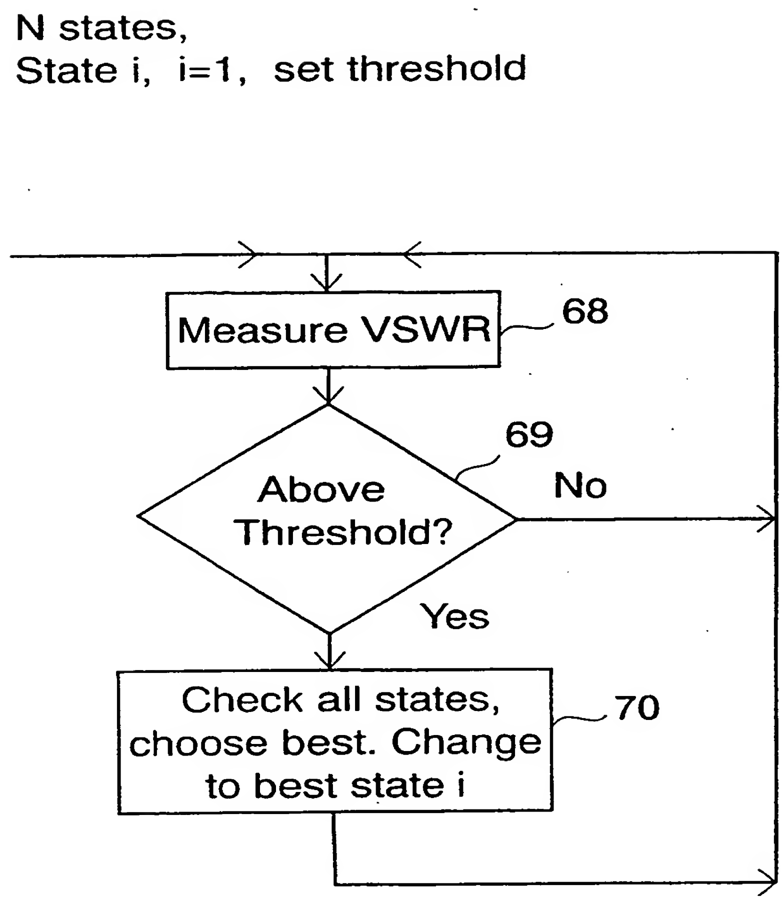
N states,
State i, i=1, set threshold
Measure VSWR
68
69
Above Threshold?
No
Yes
Check all states, choose best. Change to best state i
70

Fig. 16

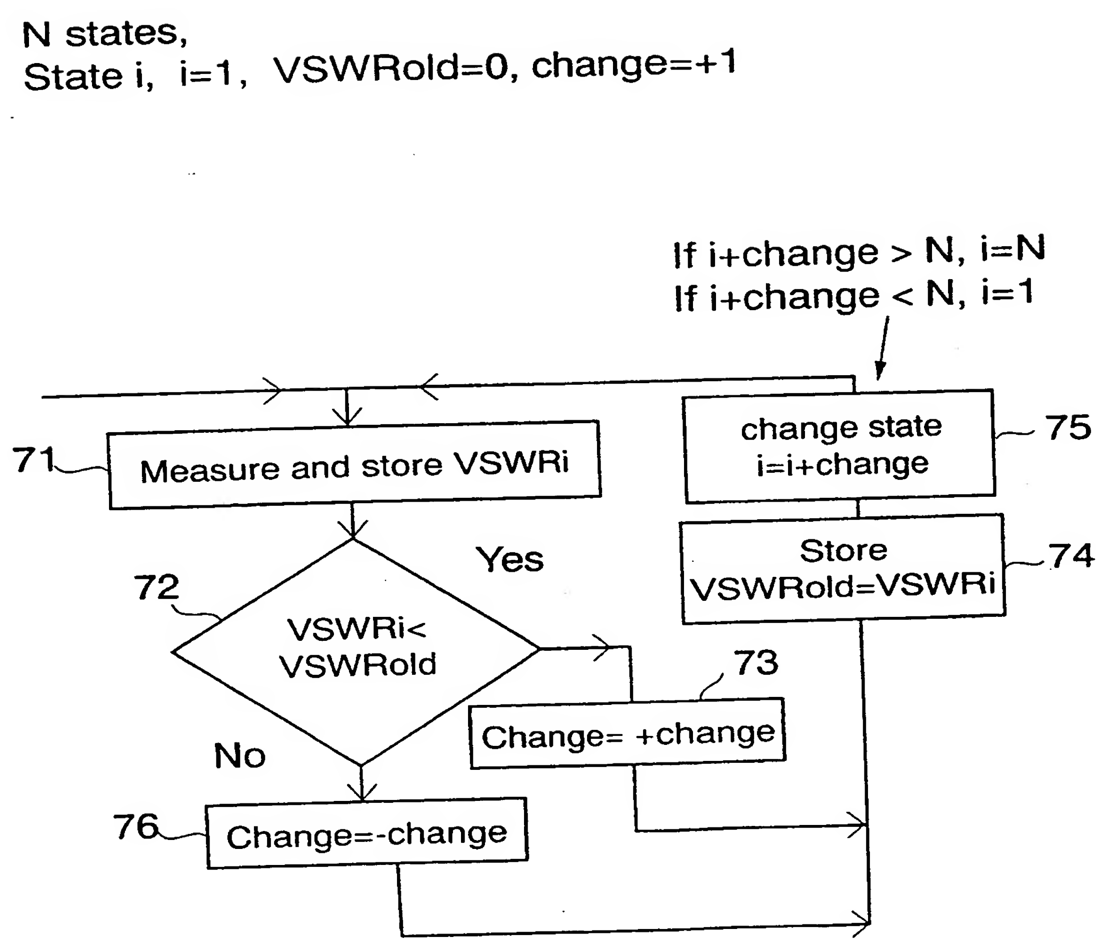
N states,
State i, i=1, VSWRold=0, change=+1
If i+change > N, i=N
If i+change < N, i=1
71
Measure and store VSWRi
72
VSWRi<
VSWRold
Yes
No
73
Change= +change
76
Change=-change
75
change state
i=i+change
74
Store
VSWRold=VSWRi

Fig. 17

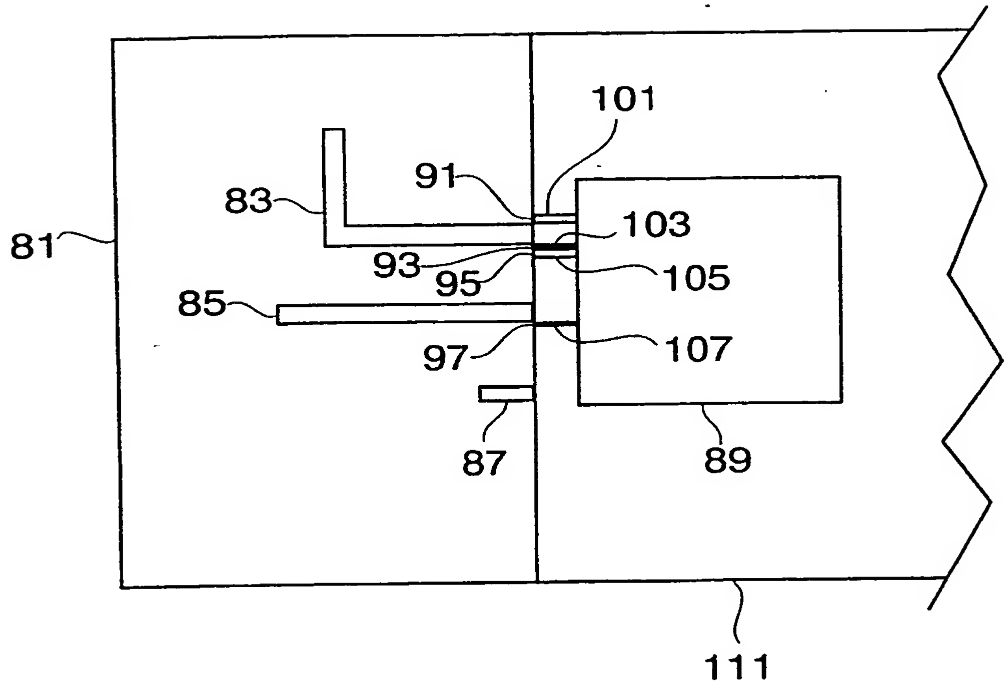

Fig. 18

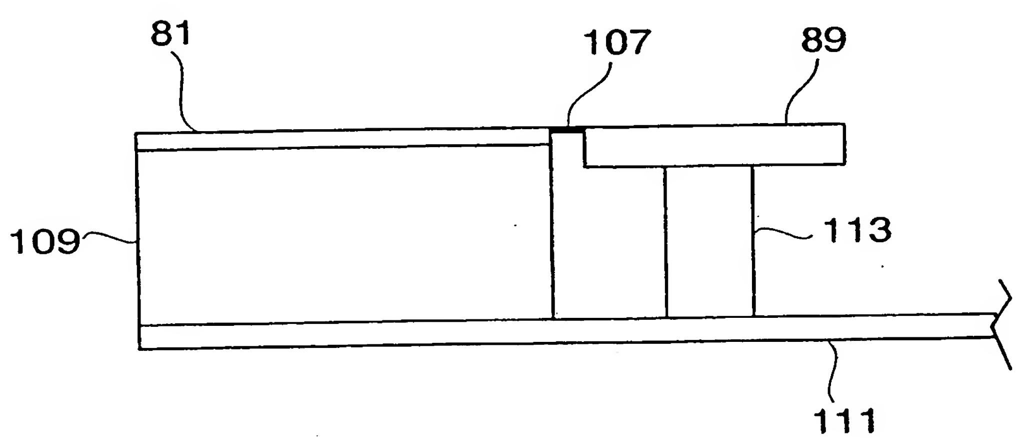

Fig. 19

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/02058

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H01Q 1/36, H01Q 3/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H01Q, H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5541614 A (JUAN F. LAM ET AL), 30 July 1996 (30.07.96), column 2, line 31 - line 41, abstract --	1,34
A	US 5933122 A (JüRGEN SAUER ET AL), 3 August 1999 (03.08.99), column 2, line 25 - line 30 --	1,34
A	Patent Abstracts of Japan, abstract of JP 10-209932 A (SAITAMA NIPPON DENKI KK), 7 August 1998 (07.08.98) --	1,34

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search

12 February 2001

Date of mailing of the international search report

19 -02- 2001

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/02058

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5463406 A (LOUIS J. VANNATTA ET AL), 31 October 1995 (31.10.95), column 4, line 20 - line 31 --	1,34
A	EP 0197650 A2 (BSH ELECTRONICS LIMITED), 15 October 1986 (15.10.86), claims 1,5 --	1,34
P,A	WO 0067342 A1 (NOKIA MOBILE PHONES LIMITED), 9 November 2000 (09.11.00), abstract -- --------	1,34

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/SE 00/02058

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